APPENDIX A

AFFINITY LAWS, MODEL RELATIONSHIPS AND GENERATOR SPEEDS VERSUS NUMBER OF POLES

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A1. PUMP AFFINITY LAWS

With Impeller Diameter Held Constant	With Speed Held Constant
$\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$	$\frac{Q_1}{Q_2} = \frac{D_1}{D_2}$
$\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2$	$\frac{H_1}{H_2} = \left(\frac{D_1}{D_2}\right)^2$
$\frac{Bhp_1}{Bhp_2} = \left(\frac{N_1}{N_2}\right)^3$	$\frac{Bhp_1}{Bhp_2} = \left(\frac{D_1}{D_2}\right)^3$

A2. PUMP MODEL RELATIONSHIPS

$\frac{N_1}{N_2} = \frac{D_2}{D_1} \times \left(\frac{H_1}{H_2}\right)^{1/2}$	$\frac{H_1}{H_2} = \left(\frac{Q_1}{Q_2}\right)^{2/3} \times \left(\frac{N_1}{N_2}\right)^{4/3}$
$\frac{Q_1}{Q_2} = \left(\frac{D_1}{D_2}\right)^2 \times \left(\frac{H_1}{H_2}\right)^{1/2}$	$\frac{Q_1}{Q_2} = \frac{N_1}{N_2} \times \left(\frac{D_1}{D_2}\right)^3$
$\frac{P_1}{P_2} = \left(\frac{H_1}{H_2}\right)^{3/2} \times \left(\frac{D_1}{D_2}\right)^2$	$\frac{P_1}{P_2} = \left(\frac{N_1}{N_2}\right)^3 \times \left(\frac{D_1}{D_2}\right)^5$

When $H_1 = H_2$

Then $\frac{H_1}{H_2} = \left(\frac{D_1}{D_2}\right)^2 \times \left(\frac{N_1}{N_2}\right)^2 = 1$

Therefore $\frac{D_1}{D_2} = \frac{N_2}{N_1}$

Note: Subscript 1 refers to model pumps.
Subscript 2 refers to prototype pumps.

and $$\frac{Q_2}{Q_1} = \left(\frac{D_2}{D_1}\right)^3 \times \frac{N_2}{N_1} = \left(\frac{D_2}{D_1}\right)^3 \times \frac{D_1}{D_2} = \left(\frac{D_2}{D_1}\right)^2$$

$$\frac{P_2}{P_1} = \left(\frac{D_2}{D_1}\right)^5 \times \left(\frac{N_2}{N_1}\right)^3 = \left(\frac{D_2}{D_2}\right)^5 \times \left(\frac{D_1}{D_2}\right)^3 = \left(\frac{D_2}{D_1}\right)^2$$

$$N_s = \frac{N \times Q^{1/2}}{H^{3/4}}$$ Where Q is in gpm, N is RPM, and H is in feet.

$$whp = \frac{W \times CFS \times H}{550} = \frac{S \times GPM \times H}{3960}$$

Where W is specific weight of water (lb/ft^3)

S is specific weight of liquid referred to water at $68^{\circ}F$

H is turbine net head in feet

$$eff = \frac{whp}{bhp} \qquad \sigma = \frac{NPSH}{H}$$

A3. TURBINE AFFINITY LAWS

For Constant Diameter

$$\frac{P_1}{P_2} = \left(\frac{H_1}{H_2}\right)^{3/2}$$

$$\frac{N_1}{N_2} = \frac{Q_1}{Q_2} = \left(\frac{H_1}{H_2}\right)^{1/2}$$

For Constant Head

$$\frac{N_1}{N_2} = \frac{D_2}{D_1}$$

$$\frac{Q_1}{Q_2} = \left(\frac{D_1}{D_2}\right)^2 = \frac{P_1}{P_2}$$

A4. TURBINE MODEL RELATIONSHIPS

$$\frac{N_1}{N_2} = \frac{D_2}{D_1} \times \left(\frac{H_1}{H_2}\right)^{1/2}$$

N_R = Prototype Runaway Speed

$$N_R = \frac{1838 \times \phi \times (H_2)^{1/2}}{D_2}$$

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2} \times \left(\frac{D_1}{D_2}\right)^3$$

$$\frac{HP_1}{HP_2} = \left(\frac{H_1}{H_2}\right)^{3/2} \times \left(\frac{D_1}{D_2}\right)^2$$

$$\frac{Q_1}{Q_2} = \left(\frac{D_1}{D_2}\right)^2 \times \left(\frac{H_1}{H_2}\right)^{1/2}$$

$$\frac{HP_1}{HP_2} = \left(\frac{N_1}{N_2}\right)^3 \times \left(\frac{D_1}{D_2}\right)^5$$

$$\sigma = \frac{H_b - H_v - H_s}{H}$$

Roger's Curve: $\sigma = \frac{N_s^2}{16{,}000}$

$$\Phi = \frac{N \times D}{1838 \times H^{1/2}}$$

$$N_s = \frac{N \times P^{1/2}}{H^{5/4}}$$

$$Q = \frac{HP \times 8.8}{H \times eff}$$

Turbine Shaft Diameters: $d = \frac{321{,}000 \times HP^{1/3}}{N \times Stress}$ (solid shafts)

Hollow Shafts: $s = \frac{321{,}000 \times HP \times d}{N\,(d^4 - d_1^4)}$ (d_1 is inside diameter)

A5. GENERATOR SPEEDS vs NUMBER OF POLES

$$RPM = \frac{120 \times Hz}{n} \qquad \text{For 60 cycles: } RPM = \frac{7{,}200}{n}$$

Hz = Frequency in cycles per second

n = No. of Poles

60 Hz Synchronous Speeds

Poles	RPM	Poles	RPM	Poles	RPM
24	300.0	60	120.0	104	69.2
26	277.0	64	112.4	110	65.5
28	257.1	68	105.9	112	64.3
30	240.0	70	102.9	120	60.0
32	225.0	72	100.0	126	57.1
36	200.0	76	94.7	128	56.2
40	180.0	80	90.0	130	55.4
42	171.4	84	85.7	132	54.5
44	163.6	88	81.8	136	52.9
48	150.0	90	80.0		
50	144.0	96	75.0		
52	138.5	98	73.5		
56	128.6	100	72.0		

Note: Omit Poles 34, 38, 54, 58, 62, 66, 72, and 82.